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West Coast Vancouver Island Pacific Cod Assessment: 2002

Évaluation de la morue du Pacifique de la côte ouest de l'île de Vancouver en 2002

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ABSTRACT

The 2001 assessment of the west coast of Vancouver Island Pacific cod stock was updated for 2002 by adding an additional year of catch data and new CPUE index, incorporating abundance indices derived from a shrimp trawl survey, and converting model catch data from a calendar year basis to standard DFO fishing years (1 April to 31 March). Catch and effort data from a shrimp trawl survey operated by DFO since 1973 were analysed for consistency of coverage over the history of the survey. Tows were retrospectively assigned to areal strata and an index of abundance was calculated for each year by treating the tows as if they had been randomly sampled, weighting the stratum CPUE by the area of the stratum. The resulting indices were very similar to the indices previously estimated using an interpolation method as well as being similar to the CPUE indices calculated from the commercial fishery since 1988.

Two versions of a delay-difference assessment model were used to predict the response of the stock to varying fishing levels for the 2003/04 fishing year, one which used the shrimp trawl abundance data and the second which left out these data to maintain comparability with the 2001 assessment. The shrimp trawl index for May 2002 was used directly as an abundance index for the 2002/03 fishing year in the assessment model which used the shrimp trawl data and the index was used indirectly to predict the 2002/03 CPUE index for the assessment model which did not use the shrimp trawl data. Both models showed that the stock had increased since the previous assessment and the model catch predictions indicated that higher catches could be taken in 2003/04. The respective assessment models, with and without the shrimp trawl indices, estimated the biomass levels at the beginning of 2002/03 at 104% and 39% of B_{MSY}. Respective catch levels that maintained the same stock size between 2003/04 and 2004/05 were estimated at 690 t and 570 t for each model. The respective catch levels which corresponded to F_{MSY} were estimated at 1,290 t and 510 t for each model. The assessment model which incorporated the shrimp trawl data was preferred as it included all of the available data for this stock. The B_{MSY} and F_{MSY} reference points are not well estimated and future models should provide estimates of parameter uncertainty.

RÉSUMÉ

Pour 2002, nous avons mis à jour l'évaluation 2001 du stock de morue du Pacifique de la côte ouest de l'île de Vancouver en y ajoutant une année supplémentaire de données sur les captures, un nouvel indice de PUE et des indices d'abondance obtenus par un relevé au chalut à crevettes, ainsi qu'en transformant les données sur les prises du modèle exprimées selon l'année civile en données exprimées selon l'année de pêche standard du MPO (du 1er avril au 31 mars). Nous avons analysé les données obtenues par le relevé au chalut à crevettes qu'effectue le MPO depuis 1973 afin d'assurer l'uniformité de la couverture du relevé durant ces années. Nous avons rétrospectivement assigné les traits de chaluts à des strates surfaciques et avons calculé un indice d'abondance pour chaque année en considérant les traits comme des échantillons aléatoires et en pondérant les PUE pour chaque strate par la superficie de cette dernière. Les indices ainsi obtenus ressemblent beaucoup aux indices estimés auparavant par une méthode d'interpolation et aux indices de PUE calculés à partir des données de la pêche commerciale depuis 1988.

Nous nous sommes servis de deux versions d'un modèle d'évaluation à différences retardées afin de prédire la réaction du stock à diverses intensités de pêche pour l'année 2003-2004 : une version qui utilise les données d'abondance obtenues par le relevé au chalut à crevettes et l'autre qui omet ces données pour donner des résultats comparables à ceux de l'évaluation de 2001. Dans le modèle d'évaluation comprenant les données de relevé au chalut, nous avons utilisé directement l'indice du relevé de mai 2002 comme indice d'abondance pour l'année 2002-2003, alors que nous avons utilisé indirectement l'indice du relevé pour prédire les PUE de 2002-2003 dans l'autre modèle. Les deux modèles montrent que la taille du stock a augmenté depuis l'évaluation précédente et qu'un plus grand nombre de morues pourraient être capturées en 2003-2004. Le modèle avec les indices du relevé au chalut et le modèle sans ces indices nous ont permis d'estimer respectivement à 104 % et 39 % de la B_{MSY} la biomasse du stock au début de 2002-2003, à 690 t et 570 t les captures qui permettrait de maintenir la même taille du stock de 2003-2004 à 2004-2005, et à 1 290 t et 510 t les captures qui correspondent à F_{RMS}. Le modèle d'évaluation avec les données du relevé au chalut a été préféré puisqu'il comprend toutes les données disponibles sur ce stock. Les points de référence B_{RMS} et F_{RMS} ne sont pas bien estimés, et les modèles futurs devraient fournir des estimations de l'incertitude des paramètres.

1.0 INTRODUCTION

An assessment of the Pacific cod (*Gadus macrocephalus*) population off the west coast of Vancouver Island was presented to the Department of Fisheries (DFO) Pacific Stock Assessment Review Committee (PSARC) in 2001 (Sinclair et al. 2001). This assessment concluded that the west coast Vancouver Island (WCVI) Pacific cod population was below its calculated optimum and the stock abundance would decrease if catch levels exceeded about 400 t in 2002/03. As the allowable catch (the previous TAC plus carry-over) at that time for this species in this area was close to 900 t, DFO management reduced the TAC to 200 t for the year beginning 1 April 2002. However, there were reports in spring and summer 2002 from experienced fishermen that Pacific cod abundance has increased off the west coast of Vancouver Island since the assessment put forward by Sinclair et al. (2001). This conclusion was driven by unexpectedly high levels of bycatch even when Pacific cod were being avoided. The biomass index from the shrimp trawl survey conducted in May 2002 also showed a strong increase relative to the previous year.

The assessment predictions made by Sinclair et al. (2001) indicated that the biomass of this population was expected to increase under the reduced catch levels. However, one interpretation of the reports of high rates of bycatch and the recent higher observation from the shrimp trawl survey is that there has been a quicker than anticipated recovery for this population. Therefore, this paper, at the request of the fishing industry and the Canadian Groundfish Research and Conservation Society (CGRCS), has undertaken to repeat the previous assessment of Pacific cod on the west coast of Vancouver Island by updating the available data and including a new index of abundance. This is the result of a suggestion by Sinclair et al. (2001) to incorporate the biomass indices for Pacific cod taken from the west coast Vancouver Island shrimp trawl survey due to an apparent good correspondence between this index and the abundance indices derived from commercial catch and effort data.

The primary reason to undertake this work is the concern on the part of industry that the abundance of this species could increase so quickly that the catches of other target species on the west coast of Vancouver Island could be curtailed due to unavoidable bycatch of Pacific cod.

2.0 DATA SOURCES

2.1 COMMERCIAL TRAWL DATA

DFO maintained records of groundfish catch and effort data from 1954 to 1995 using a combination of voluntary skipper interviews, vessel logbooks, landings records (sales slips or validation records) and observations at the waterfront. These data are archived in the GFCATCH database (Leaman and Hamer 1985), which has recently been described in detail by Rutherford (1999).

A mandatory at-sea observer program was implemented for most Option A and some Option B trawl vessels in early 1996. This includes about 90% of the entire British Columbia trawl fleet and every vessel which fishes for Pacific cod on the west coast of Vancouver Island. The observers provide information on catch locations, bridge log data and species composition (by weight), including estimates of the weight of all discarded fish. A relational database, PacHarvest, was

developed by the DFO Groundfish Section concerned with slope rockfish assessment (Schnute et al. 1999) which is located at the Pacific Biological Station, Nanaimo, B.C.

2.2 COMMERCIAL SAMPLING DATA

The historical size composition data for the west coast Vancouver Island from 1956–2001 were taken from Sinclair et al. (2001). These samples were combined by quarter after weighting individual samples by the ratio of catch divided by sample weight. For the at-sea samples, the catch weight was the weight of the catch of the bottom trawl tow from which the sample was drawn. For port samples, the catch weight was the weight of the landing.

2.3 SHRIMP TRAWL SURVEY INDEX

A shrimp trawl survey has been conducted since 1973 in most years by DFO off the west coast of Vancouver Island, although the spatial coverage of the survey has varied between years. The most continuous coverage has been in Pacific Fisheries Management Area (PFMA) 124 (Figure 1) which has been sampled in each year that the survey was conducted (there were no surveys in 1974, 1984, and 1986). PFMA 125 was not sampled during the 1989 and 1991 surveys and PFMA 121 and 123 were added to the survey design in 1996 and have been surveyed in each year since then. The catch weight of Pacific cod has been recorded throughout the time series but no size or other biological information for this species were collected.

A description of the design of this survey, including most changes which might have affected the catch of Pacific cod, is provided in Sinclair et al. (2001).

3.0 DATA PREPARATION

3.1 CPUE INDEX

Catch and effort data were assembled from GFCATCH and PacHarvest from 1 January 1956 to 31 March 2002. We used similar criteria to develop a CPUE index as used by Sinclair et al. (2001). All bottom trawl trips which fished in DFO Area 3C were selected from this dataset, and were further confined to the months of April to December and to those tows which fished at depths less than 200 m. A departure in criteria was that all tows which had a success code greater than 1 (these are failed tows in the PacHarvest data only) were dropped, as well as any tows which had missing effort or depth data. Tows which failed to record any catch of any species were also dropped as these would likely be an indication of failed tows in the GFCATCH database.

A CPUE (β_y) series (Table 1) was constructed from the remaining tows based on the formula:

$$\beta_y = \frac{\sum_{k=1}^{N_y} Catch_{y,k}}{\sum_{k=1}^{N_y} Duration_{y,k}} \qquad \text{Eq. 1}$$

where N_y is the number of records in the data set for year y, $Catch_{y,k}$ is the recorded catch of Pacific cod in kg for each record and $Duration_{y,k}$ is the number of hours towed for each record. The estimated series of CPUE indices generated by this extraction is extremely close to the equivalent CPUE series prepared by Sinclair et al. (2001), with small deviations between the two series in some years probably due to differences in grooming assumptions. The relative index for 2001 has increased about 50% relative to the 2000 index but has not reached the levels of the early 1990s (Table 1).

3.2 ANNUAL CATCH TOTALS

Total catches for Pacific cod from DFO Areas 3C and 3D were generated from the GFCATCH database from 1956 to 1995 but the annual catch totals from this database before 1979 differ from the annual catches used in the 2001 WCVI Pacific cod assessment (Sinclair et al. 2001). This is because there was considerable catch of Pacific cod by the foreign fleet prior to the declaration of the Canadian EEZ which are not present in GFCATCH. This difference was documented by Sinclair et al. (2001) and the higher catch totals reported in that paper are used in the assessment (Table 1).

Table 1. Observations of average weight (kg), CPUE (kg/h), catch (t), and effort (hours) by fishing year (1 April to 31 March). Minus one (-1) indicates that data are missing for that cell. Catches prior to 1980 and average weight data taken from Sinclair et al. (2001). All CPUE and catch data from 1980 are summarised from GFCATCH and PacHarvest. Effort for fishing year *fyear* was calculated: $Effort_{fyear} = Catch_{fyear} / CPUE_{fyear}$

Year	Average weight (kg)	CPUE (kg/h)	Catch (t)	Effort (h)	Year	Average weight (kg)	CPUE (kg/h)	Catch (t)	Effort (h)
56/57	2.53	126	1436	11433	79/80	2.36	361	1544	4282
57/58	2.30	199	1805	9094	80/81	2.27	228	1129	4948
58/59	2.23	173	836	4816	81/82	1.99	192	1524	7933
59/60	2.49	130	902	6915	82/83	2.18	82	611	7407
60/61	2.60	66	620	9432	83/84	1.94	66	887	13390
61/62	2.49	58	463	8034	84/85	1.88	53	508	9525
62/63	1.98	88	794	9013	85/86	2.02	30	441	14511
63/64	1.92	234	1307	5593	86/87	2.51	66	441	6629
64/65	2.44	268	1621	6053	87/88	2.04	124	1404	11334
65/66	2.34	202	2923	14463	88/89	2.08	237	3163	13351
66/67	2.06	306	3098	10137	89/90	2.78	135	1965	14553
67/68	2.47	156	1957	12532	90/91	3.24	161	2082	12961
68/69	2.58	83	1096	13190	91/92	2.53	82	2977	36281
69/70	2.27	106	1001	9487	92/93	2.06	78	2233	28616
70/71	1.84	140	1383	9902	93/94	2.55	89	2096	23631
71/72	1.87	358	4556	12724	94/95	1.74	31	790	25771
72/73	1.90	419	5774	13792	95/96	2.48	18	253	13799
73/74	2.23	295	3314	11247	96/97	1.29	11	140	12459
74/75	2.14	334	3811	11401	97/98	-1	21	134	6343
75/76	2.22	260	4077	15703	98/99	1.75	18	51	2808
76/77	2.20	203	3211	15816	99/00	1.49	25	74	2919
77/78	2.35	190	2264	11939	00/01	2.83	44	129	2955
78/79	2.50	255	1508	5922	01/02	1.65	64	339	5289

The combined GFCATCH and PacHarvest dataset for Major Areas 3C and 3D was used to generate a series of catch totals defined by the standard DFO fishing year currently used for management (1 April to 31 March; Table 1). This was done to ensure that the assessment advice presented for Pacific cod is consistent with the requirements for management advice to set Total Allowable Catches for a fishing year. The assessment by Sinclair et al. (2001) was based on a summarisation by calendar year ending 31 December. This meant that model projections based on a calendar year would have included a spawning season which had already been completed, given that the Pacific cod spawning season takes place from January to March, t

The catch data were separated into two intervals: January-March (=spawning season) and April-December (=non-spawning season) and the following formula was applied to the catches (including the foreign fleet catches) used in the assessment model to calculate the catch by fishing year *fyear*:

$$Catch_{fyear} = Catch_{year} * p_{non-spawn_{year}} + Catch_{year+1} * p_{spawn_{year+1}} \qquad \textbf{Eq. 2}$$

where $p_{spawn_type_y}$ is the proportion of annual catch in each period for *year* calculated from the domestic catch dataset. The CPUE series is unaffected by this switch in year definition as it confined to the non-spawning period of April to December.

3.3 SHRIMP TRAWL INDEX

The density of cod by weight per square metre was calculated for all tows using the distance travelled for each tow and assuming a constant door spread consistent with the net used in each year of the survey. The Pacific cod biomass indices reported in Sinclair et al. (2001) were estimated from the sample tow density using an inverse distance weighted procedure (described in Sinclair et al. 2001) and which are referenced in this paper as the "interpolated index".

An alternative shrimp trawl index for Pacific cod was estimated based only on tows which were made in areas consistently surveyed over the full history of the series. This involved restricting the tows to sets which were made in consistent areas within PFMA areas 124 and 125, including the reassignment of some tows which were coded in adjacent areas but were physically in the consistently surveyed areas. Some outlier tows were dropped. The final outcome dropped 25 tows, moved 47 tows from 123 to 121 and 11 tows from 123 to 124 (Table 2) from a total of 2,553 tows over the entire history of the survey (Table 3). Boxes were then drawn around each aggregation of selected tows to generate areal strata which were used to weight the average density of Pacific cod from each area and year of the survey (Figure 1). The constant area weightings used in the calculations are provided in Table 4.

Table 2. Summary table of changes made to the allocation of areas in the shrimp trawl survey database.

Old Area	New Area					
	121	123	124	125	Dropped	Total
121	120	0	0	0	1	121
123	47	159	0	0	8	214
124	0	11	1649	0	2	1662
125	0	0	0	542	14	556
Total	167	170	1649	542	25	2553

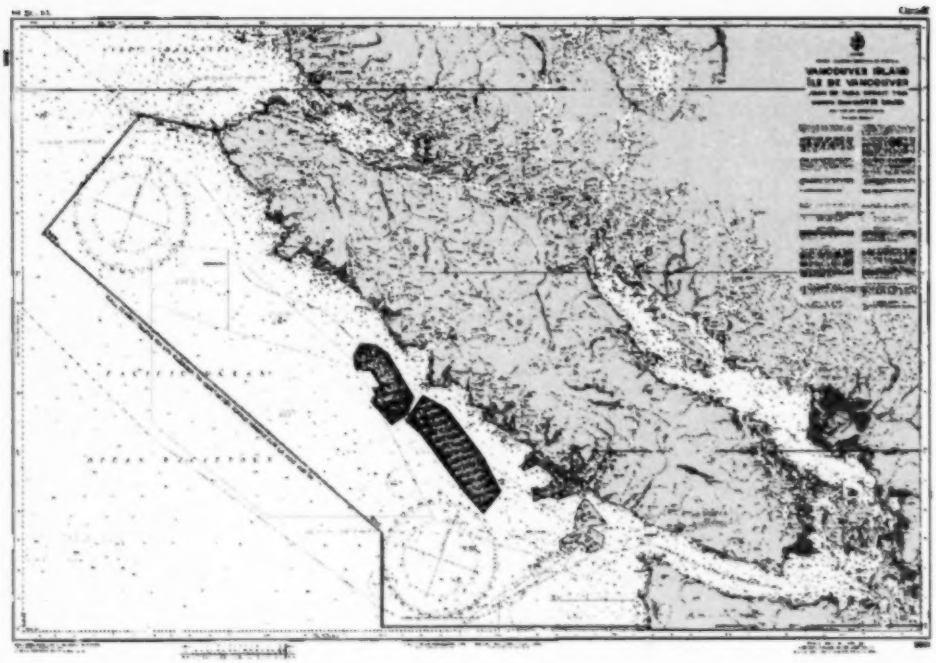

Figure 1. Enclosed areas estimated from consistent tow locations in the west coast Vancouver Island shrimp trawl survey: 1973-2002.

Table 3. Distribution of available tows by revised area (Table 2) and year.

Year	121	123	124	125	Dropped	Total
1973	0	0	57	19	7	83
1975	0	0	64	18	6	88
1976	0	0	70	18	2	90
1977	0	0	55	21	0	76
1978	0	0	85	16	0	101
1979	0	0	52	25	0	77
1980	0	0	59	26	0	85
1981	0	0	58	30	0	88
1982	0	0	57	25	0	82
1983	0	0	51	26	0	77
1985	0	1	59	22	0	82
1987	0	0	55	13	0	68
1988	0	0	71	10	0	81
1989	0	0	67	0	0	67
1990	0	0	72	10	0	82
1991	0	0	87	0	0	87
1992	0	0	77	6	0	83
1993	0	0	70	33	0	103
1994	7	0	67	30	0	104

Year	121	123	124	125	Dropped	Total
1995	0	0	63	25	0	88
1996	16	22	56	17	0	111
1997	21	24	61	21	3	130
1998	25	23	44	22	1	115
1999	25	22	51	31	2	131
2000	24	25	43	30	2	124
2001	25	26	48	22	1	122
2002	24	27	50	26	1	128
Total	167	170	1649	542	25	2553

Table 4. Stratum areas (km^2) calculated from the enclosures in Figure 1.

Stratum	Area (km^2)
121	523.46
123	447.68
124	1714.32
125	969.49
Total	3654.95

A biomass index was then calculated for each year:

$$B_y = \sum_i \bar{C}_{y,i} A_i \qquad \textbf{Eq. 3}$$

where $\bar{C}_{y,i}$ = mean CPUE (kg/km^2) in year y in stratum i. CPUE was estimated for each tow t using $C_{y,i,t} = {catchweight_{y,i,t}} \Big/ {(distance_traveled_{y,i,t} * opening_{y,t})}$ and A_i = area of stratum i (km^2).

The variance of the survey biomass estimate V_y is calculated in kg^2 as follows:

$$V_y = \sum_i {Z_{y,i} A_i^2} \Big/ {n_i} \qquad \textbf{Eq. 4}$$

where Z_i = variance of CPUE (kg^2/km^4) in stratum i

n_i = number of observations in stratum i

The precision of the survey is often expressed in terms of the relative error (RE) which is approximated from the values obtained in Eq. 3 and Eq. 4:

$$RE_y = \frac{\sqrt{V_y}}{B_y} \qquad \textbf{Eq. 5}$$

There were no tows in Area 125 in 1989 and 1991 (Table 3), so the mean CPUEs and variances calculated for Area 124 for those two years were used for area 125 and weighted by the stratum area for Area 125. A comparison of mean catch rates from areas 124 and 125 showed no significant difference between these two areas when calculated over the entire survey period. This new index was standardised relative to the geometric mean for 1973, 1975-83, 1985, 1988-2002 $\left[b^0_{year} = e^{(\hat{\beta}_{year} - \bar{\beta}_{73,75-83,85,88-2002})}\right]$ for comparison with the "interpolated index (Sinclair et al. 2001). The revised biomass indices (Table 5; Figure 2 [confidence bounds based on the *RE*s in Table 5, assuming a lognormal error structure]) are very similar to the previously calculated "interpolated" indices. Note that the most recent survey, which occurred in May 2002, shows a nearly threefold increase relative to the previous survey and appears to have returned to levels observed in the early 1990s.

A closer comparison of the three available indices for Pacific cod is provided in Figure 3. Here the CPUE index from 1988 to 2001 is directly compared to the previous "interpolated" index and the index provided in Table 5. It can be seen from this comparison that there is good correspondence between all three sets of indices and that there is very little difference between the "interpolated" and the revised biomass indices except for 1988 and 1991. Note that the "interpolated" index has also duplicated the 1989 and 1991 indices for Area 124 for Area 125 to allow comparability to the revised biomass index.

Table 5. Biomass index calculated from Eq. 3, standard error $\left(\sqrt{V_y}\right)$, and *RE* (Eq. 5) for the combined areas 124 and 125.

Year	Biomass Index (t)	Standard error	*RE*	Year	Biomass Index (t)	Standard error	*RE*
1973	290.5	148.0	51%	1990	788.1	183.8	23%
1975	1830.8	292.5	16%	1991	792.3	121.3	15%
1976	1429.3	288.6	20%	1992	459.7	169.5	37%
1977	1906.4	684.6	36%	1993	369.6	79.0	21%
1978	382.7	118.0	31%	1994	440.1	145.6	33%
1979	763.7	364.0	48%	1995	120.9	61.5	51%
1980	420.8	179.4	43%	1996	106.1	35.1	33%
1981	1075.2	493.3	46%	1997	236.8	73.9	31%
1982	188.5	109.6	58%	1998	93.8	49.4	53%
1983	57.0	18.9	33%	1999	279.3	97.5	35%
1985	53.7	23.6	44%	2000	301.9	73.1	24%
1988	1772.1	635.9	36%	2001	273.1	141.2	52%
1989	2711.7	1157.2	43%	2002	811.3	187.2	23%

A further index can be developed using data from all four areas which have been surveyed by the shrimp trawl survey (Figure 1). As areas 121 and 123 have only been consistently surveyed since 1996 (Table 3), this index was only calculated for the most recent seven years (Table 6). There is also good correspondence between this index and with the "interpolated" index and the commercial fishery CPUE index (Figure 4). This index shows an increase in the May 2002 index that is comparable to the increase seen in the longer series based only on Areas 124 and 125.

Table 6. Biomass index calculated from Eq. 3, standard error $\left(\sqrt{V_y}\right)$, and *RE* (Eq. 5) for the combined areas 121, 123, 124 and 125.

Year	Biomass Index (t)	Standard error	*RE*
1996	139.3	37.8	27%
1997	303.5	78.2	26%
1998	139.0	51.5	37%
1999	413.0	106.4	26%
2000	375.0	84.1	22%
2001	387.2	157.4	41%
2002	1013.6	216.4	21%

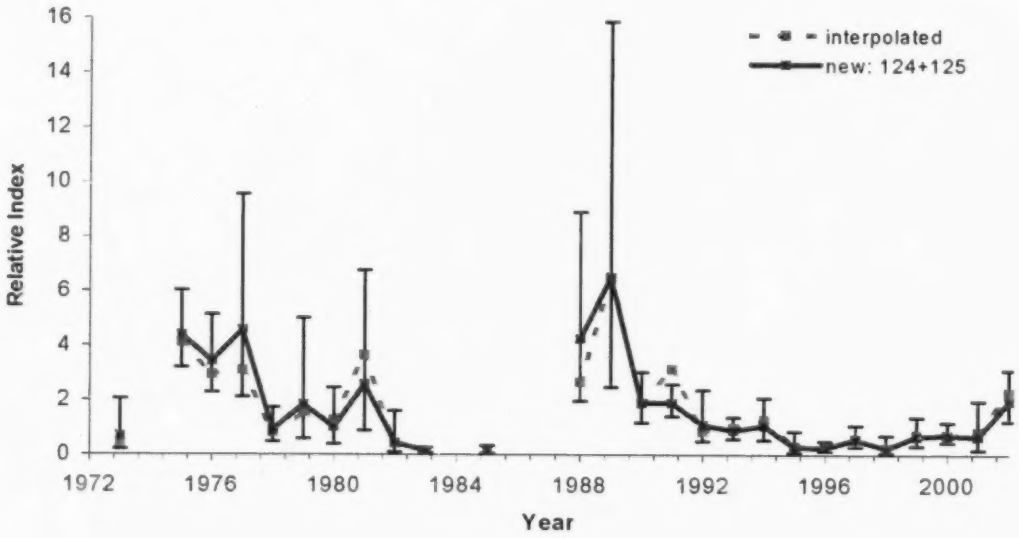

Figure 2. The revised biomass index for WCVI Pacific cod based on the DFO shrimp trawl survey in Statistical Areas 124 and 125 compared to the "interpolated" index provided by Sinclair (*pers. comm,*). The absolute indices have been converted for each series to relative indices using the procedure described in Section 3.3. Confidence bounds based on the log normal distribution are calculated from the *RE*s presented in Table 5.

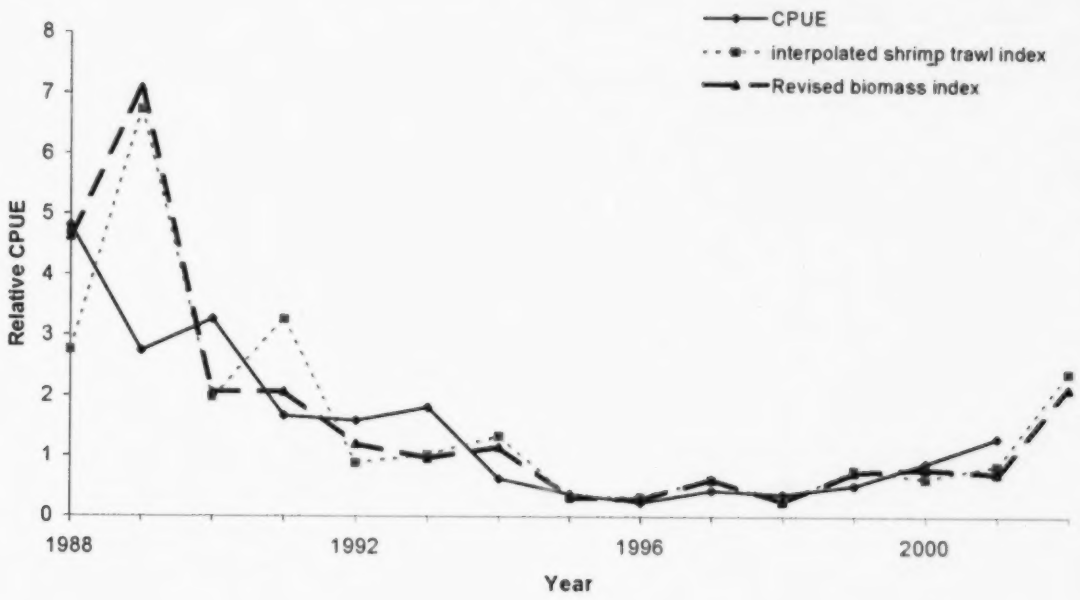

Figure 3. Comparison of three indices of Pacific cod abundance: CPUE biomass indices, the previous "interpolated" shrimp trawl index and the revised shrimp trawl biomass index based on areas 124 and 125 only (Table 5). All indices have been standardised relative to the period 1988–2001.

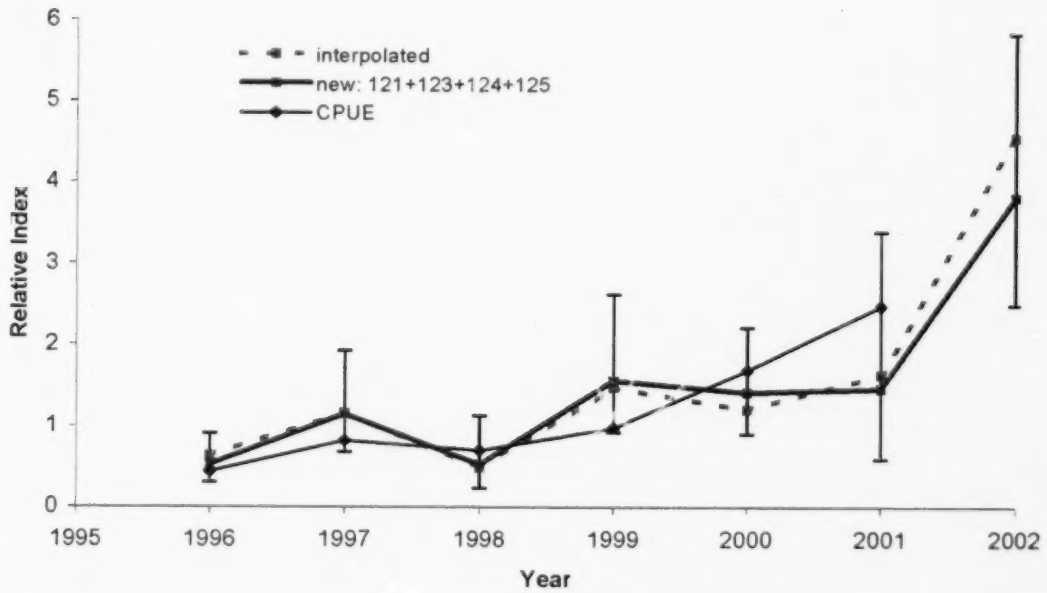

Figure 4. Comparison of three indices of Pacific cod abundance: CPUE biomass indices, the previous "interpolated" shrimp trawl index and the revised shrimp trawl biomass index based on areas 121, 123, 124 and 125 (Table 5). All indices have been standardised relative to the period 1996–2001.

3.4 PREDICTION OF 2002 CPUE VALUE

The abundance estimate for 2002 from the shrimp trawl survey (Table 5) can be used in two ways: it can either be used directly in the analysis as a data point for the shrimp trawl survey index or it can be used to predict the CPUE for 2002. The latter approach is required if the shrimp trawl data are not explicitly included in the model fitting procedure.

Examination of the relationship of these two sets of indices shows that that there is reasonable agreement between the CPUE and the shrimp biomass indices except for four surveys in the late 1970s and 1980 and a large outlier in 1989 (Figure 5). Three sets of predictions of the 2002 CPUE index were made: a) one that only used the paired observations from 1988–2001, based on the strong relationship seen in Figure 3; b) one that excluded from the regression the five outliers that can be seen in Figure 5; and 3) a regression that included all 25 pairs of observations (Table 7). The prediction fits are not strong (Figure 6) and it appears that the predictive function based on the most recent data is the most reliable for the most recent few years (Table 7). The prediction for 2002, based on the most recent data (Predicted effort 1), estimates the highest level of effort for that year while the prediction based on all the data (Predicted effort 3) estimates the lowest (Table 7). The predicted effort value based on "Predicted effort 1" was used for the analysis which did not include the shrimp trawl survey data reported in Section 5.0.

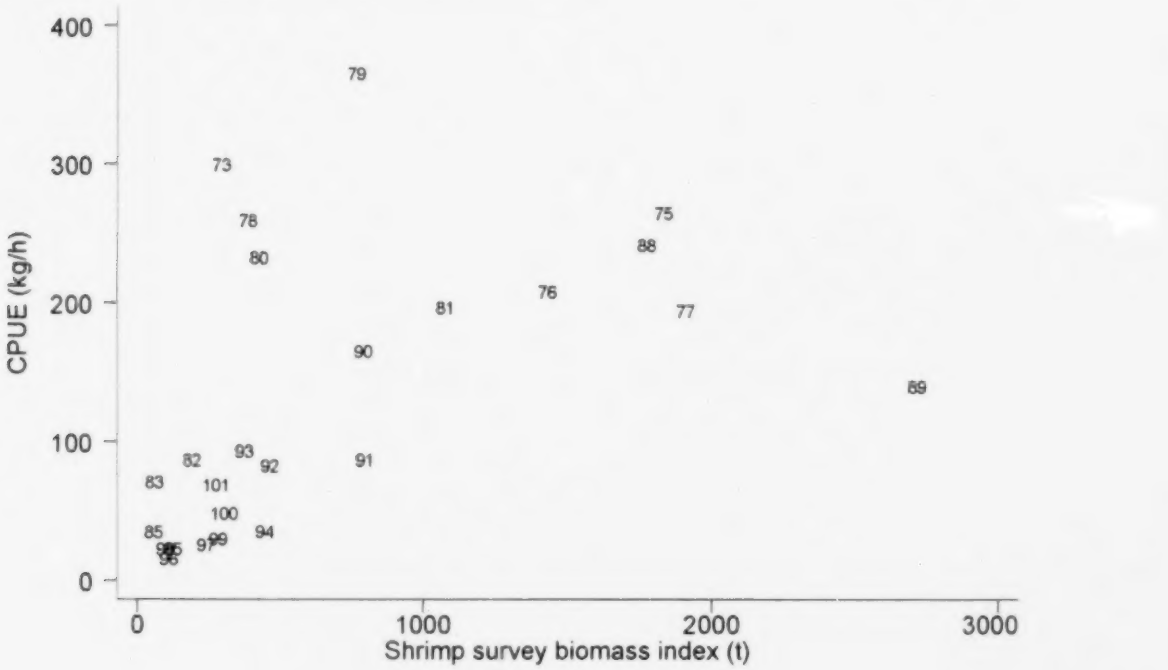

Figure 5. Annual CPUE indices (Table 1) plotted against the revised shrimp biomass indices for areas 124 and 125 (Table 5).

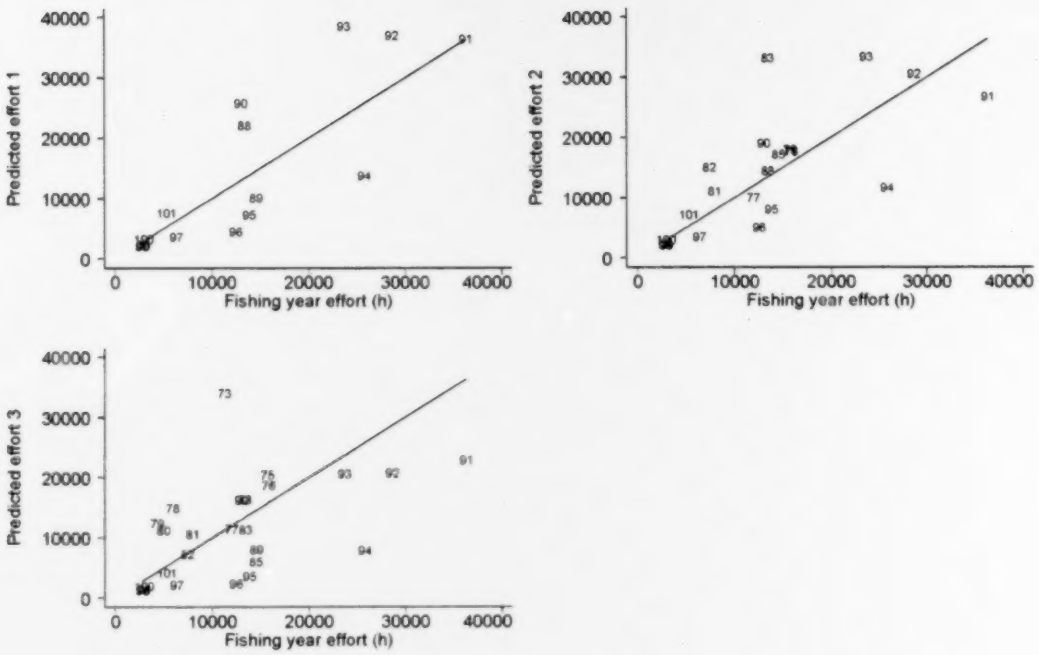

Figure 6. Plot of predicted effort against calculated effort for the three prediction methods used to estimate the effort in 2002 (Table 7).

Table 7. Comparison of calculated effort $\left(E_j = {C_j}/{CPUE_j}\right)$ against three sets of predicted effort $\left(\hat{E}_j = {C_j}/{\hat{\beta}_j}\right)$ based on the relationship of the observed shrimp trawl survey against the CPUE (β_j) in the same year. Predicted effort 1: regression only based on the paired observations from 1988-2001; predicted effort 2: regression excludes 1973, 1978-80 and 1989; predicted effort 3: uses all matched pairs of data. The shaded row at the end of the table indicates the prediction by each series for 2002–03 $\left(\hat{E}_{02/03} = {200}/{\hat{\beta}_{02/03}}\right)$. –: not estimated.

Fishing Year	Calculated effort E_j	Predicted effort 1	Predicted effort 2	Predicted effort 3
73/74	11,247	–	–	33,288
75/76	15,703	–	17,150	19,738
76/77	15,816	–	16,894	17,974
77/78	11,939	–	9,177	10,689
78/79	5,922	–	–	14,231
79/80	4,282	–	–	11,663
80/81	4,948	–	–	10,394
81/82	7,933	–	10,294	9,894
82/83	7,407	–	14,242	6,605
83/84	13,390	–	32,486	10,638
85/86	14,511	–	16,401	5,308
88/89	13,351	21,302	13,706	15,621
89/90	14,553	9,324	–	7,340
90/91	12,961	25,013	18,263	15,525

Fishing Year	Calculated effort E_j	Predicted effort 1	Predicted effort 2	Predicted effort 3
91/92	36,281	35,645	25,999	22,150
92/93	28,616	36,327	29,755	20,064
93/94	23,631	37,758	32,560	19,950
94/95	25,771	13,135	10,868	7,189
95/96	13,799	6,471	7,242	2,877
96/97	12,459	3,693	4,243	1,619
97/98	6,343	2,877	2,764	1,402
98/99	2,808	1,363	1,603	591
99/00	2,919	1,486	1,372	745
00/01	2,955	2,522	2,284	1,282
01/02	5,289	6,910	6,412	3,450
02/03	–	2,359	1,713	1,473

4.0 ASSESSMENT MODEL

A delay-difference assessment model which duplicated the model used by Sinclair et al. (2001) was coded in AD Model Builder™. The model dynamics and likelihoods were the same as those presented in Sinclair et al. (2001) and the shrimp trawl data were added to the model fitting procedure (Appendix 1). The model was fitted to the annual weight data as used by Sinclair et al. (2001; Table 1), to the observed catches by fishing year (Table 1) and to the shrimp trawl index (Table 5). The model estimated the catch data, based on an effort series calculated from the CPUE index (Table 1), the mean population weight at the beginning of the fishing year and the shrimp trawl survey biomass index, which was also assumed to occur at the beginning of the fishing year. This latter assumption is realistic, given that the shrimp survey takes place in May and the fishing year begins in April.

Separate model runs were performed. One which did not include the shrimp trawl survey data used a predicted effort for 2002/03 as a proxy for the effort that would be associated with the abundance represented by the observed May 2002 shrimp trawl survey index (series "Predicted effort 1"; Table 7). The other model run, which included the shrimp trawl survey data, did not include effort for 2002/03 but calculated the F required to take 200 t in 2002/03, given the estimated biomass at the beginning of the year.

5.0 MODEL RESULTS

Model parameter estimates differ only slightly between the two model runs (with and without the shrimp trawl data; Table 8). The estimated B_0 is lower when the shrimp survey data are included, but this is compensated by an initial scalar that is higher, giving similar starting biomass levels. The estimated M is slightly higher as is the Ricker steepness parameter when the shrimp survey data are included, but the scaling coefficients (q_c) for the catch data are similar for both model runs (Table 8). Similar differences exist when comparing the parameter estimates from fitting the model only to the catch and weight data with the equivalent parameter estimates from Sinclair et al. (2001; Table 8). The B_0 was estimated at a larger value last year (26,000 t) but the initial scalar was lower (0.39). The estimates of M, catchability, and Ricker steepness were all similar when the equivalent 2001 and 2002 assessments are compared (Table 8).

Table 8. Results for two options (depending on whether the shrimp trawl indices are included or not included in the analysis) of the WCVI Pacific cod delay-difference model based on model runs to 2002/03 and a projection over a range of catches for 2003/04. Equivalent results from the assessment model presented by Sinclair et al. (2001) are provided when available, but reference values are calculated to the noted fishing years. All biomass levels are expressed as beginning year. Catches are by fishing year (*fyear*) as presented in Table 1. NA: not applicable or not calculated. NP: no catch will raise B_{fyear} above B_{MSY}. –: not reported.

	Sinclair et al. (2001)	without shrimp trawl indices	with shrimp trawl indices
Parameter Estimates			
γ (B_1/B_0)	0.39	0.507	0.901
B_0 (unfished biomass)	26,263	21,723	14,123
M (instantaneous natural mortality)	0.42	0.465	0.579
q_c (catchability for fit to catch data)	2.06 E-05	2.001E-05	2.010E-05
q_s (catchability for fit to shrimp index)	NA	NA	6.571E-02
δ (Ricker steepness)	2.17	2.084	2.375
Standard deviation assumptions			
Weight	0.20	0.20	0.20
Catch	0.20	0.20	0.20
Shrimp trawl	NA	NA	0.20
ϕ_1	0.40	0.40	0.40
Likelihoods			
Weight	–	-9.224	11.810
Catch	–	42.175	41.200
Shrimp trawl indices	–	NA	113.410
ϕ_1	–	44.360	79.740
Total likelihood	–	77.311	246.160
Sum(observed catch)	–	74.872	74.872
Sum(predicted catch)		67.802	68.805
Derived Parameters			
F_{MSY}	0.14	0.143	0.226
B_{MSY}	12,615	10,415	6,731
F_{CRASH}	0.31	0.321	0.539
$B_{fyear-1}/B_{MSY}$	19%[1]	39%[2]	104%[2]
Catch$_{fyear}$: $B_{fyear+1}/B_{fyear}<1$	390[1]	570[2]	690[2]
Catch$_{fyear}$: $B_{fyear+1}/B_{MSY}<1$	NP	NP[2]	2,190[2]
Catch$_{fyear}$: $F_{fyear}/F_{MSY}<1$	250[1]	510[2]	1,290[2]
Residuals			
SD_weight data	–	0.9108	1.1112
SD_catch data	–	1.8013	1.7811
SD_shrimp trawl index	–	NA	3.2418
Median_absolute(weight resids)	–	0.7025	1.0250
Median_absolute(catch resids)	–	1.4610	1.2226
Median_absolute(shrimp index resids)	–	NA	1.9065

[1] *fyear* is 2002/03 for these values
[2] *fyear* is 2003/04 for these values

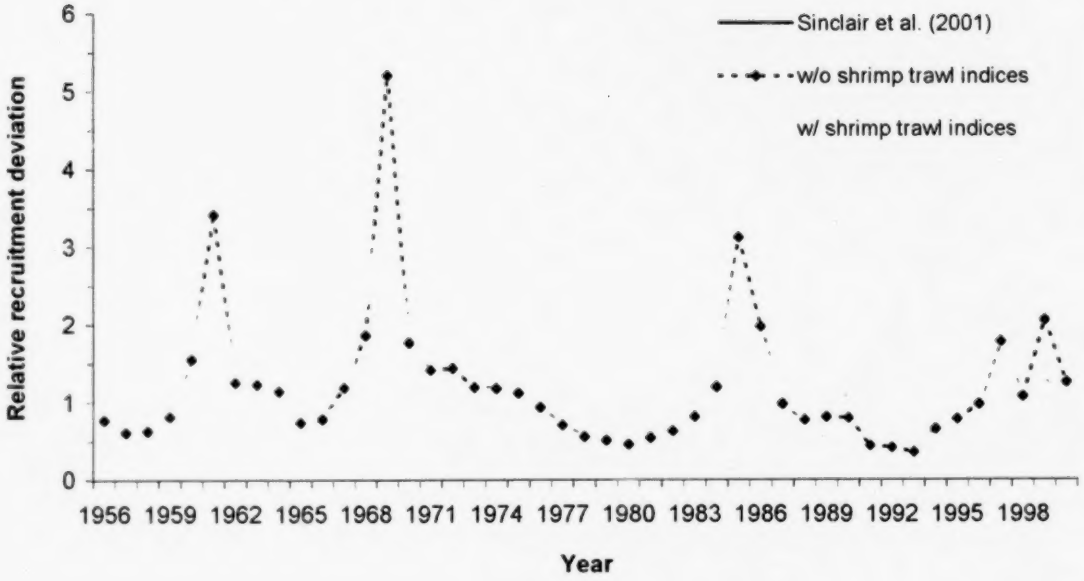

Figure 7. Comparison of the estimated recruitment deviations for the two model runs presented in Table 8 as well as the recruitment deviations from Sinclair et al (2001).

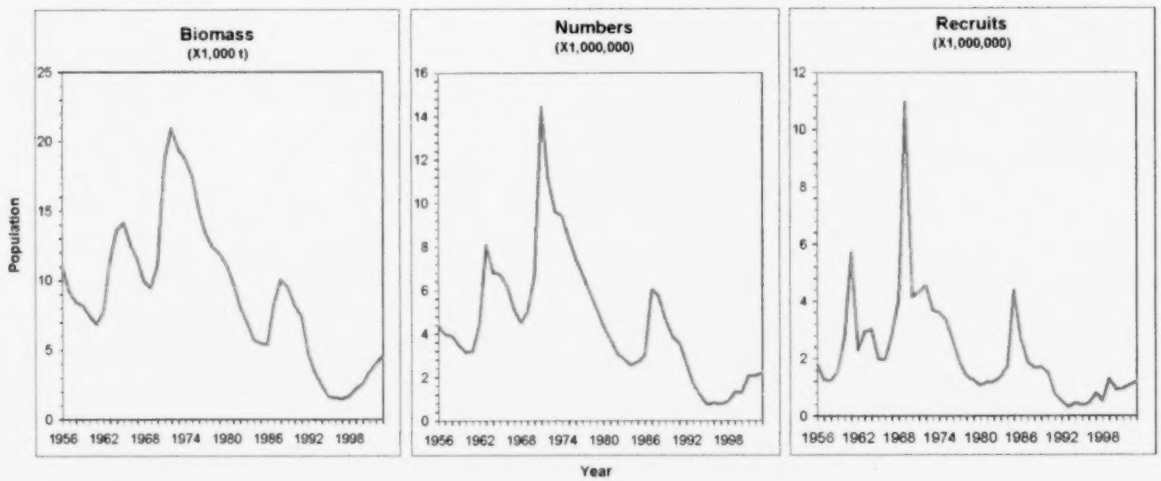

Figure 8. Population (total biomass, numbers, and number of recruits) trends for the model run which did not include the shrimp trawl data (Table 8).

A comparison of the estimated recruitment deviations shows very few differences between the three assessments, except for an elevated recruitment level in 1999 for the model without the shrimp trawl indices (Figure 7). The population trajectories estimate an increasing stock size for either model fit (Figure 8 and Figure 9), which is consistent with the increasing trajectory estimated by Sinclair et al. (2001). Detailed model output are presented for both model runs in Appendix 2.

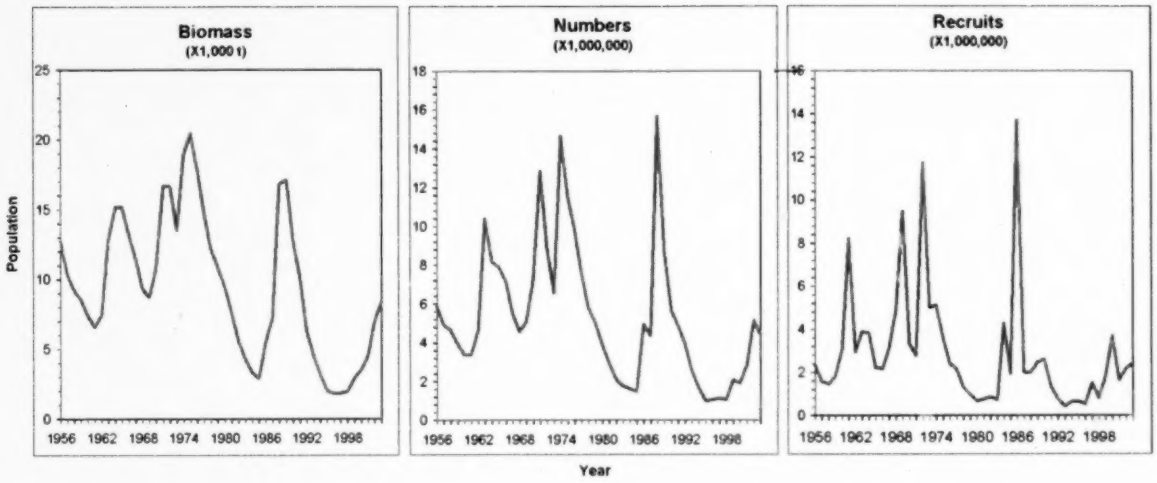

Figure 9. Population (total biomass, numbers, and number of recruits) trends for the model run which included the shrimp trawl data (Table 8).

The fits to the catch data appear to be reasonable for both models, particularly in the most recent years (Figure 10 and Figure 11). The model without the shrimp trawl data tends to underestimate the higher catch values (Figure 12) while the model which includes the shrimp trawl data tends to overestimate these values (Figure 13). Both models tend to underestimate the mean weights in the first 20 to 25 years of the model period (Figure 10 and Figure 11). There is also a strong time trend in the residuals to the fit to the mean weight data for both models, with a tendency to underestimate the early observations (Figure 12 and Figure 13). This could occur either if the model growth assumptions were not being met or if the historical data were biased low.

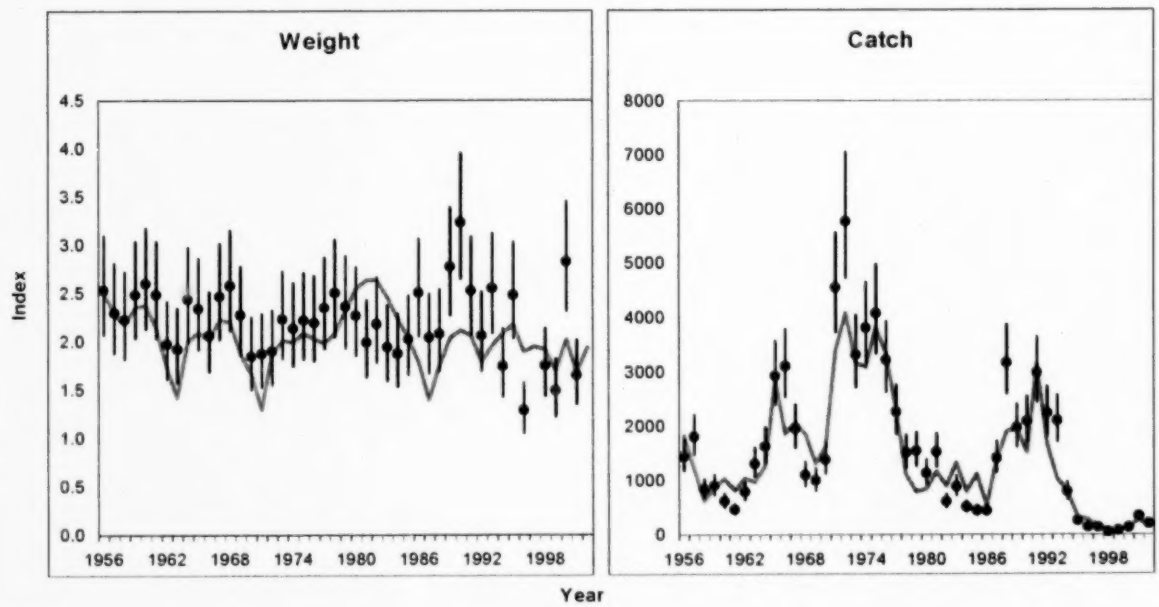

Figure 10. Model fits to the observed data for the model run which did not include the shrimp trawl data (Table 8).

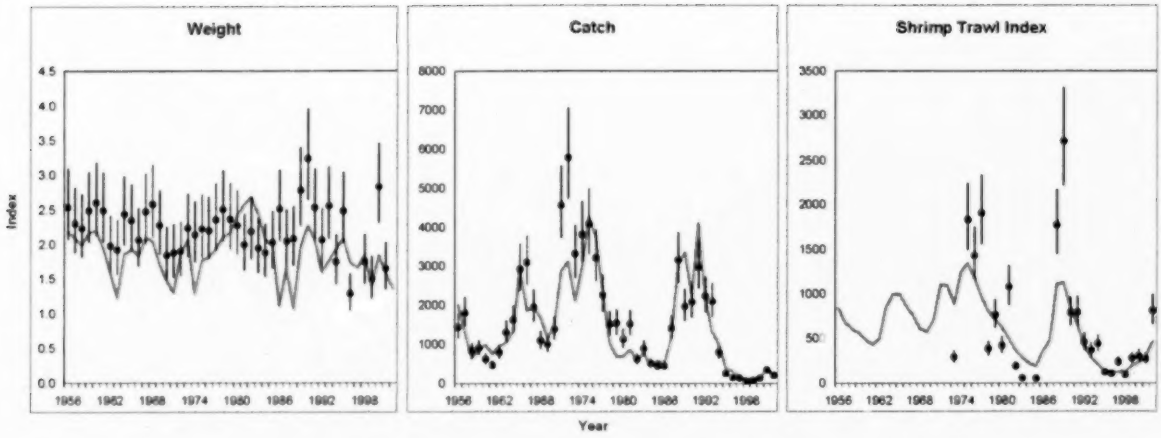

Figure 11. Model fits to the observed data for the model run which included the shrimp trawl data (Table 8).

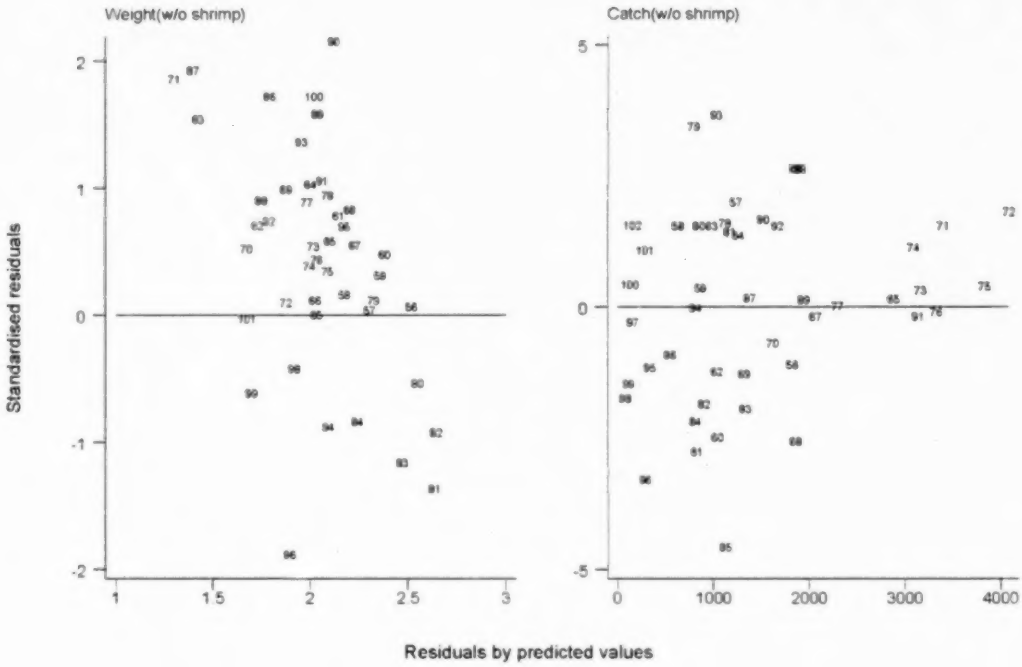

Figure 12. Residuals plotted against predicted values for the model run which did not include the shrimp trawl data (Table 8).

Model fits to the shrimp trawl biomass indices are not completely satisfactory because the model fails to capture the large peaks seen in the mid-1970s and the late 1980s (Figure 11). However, the shrimp survey indices for 1989 and 1991 are not as reliable as the other indices, given that Area 125 was not surveyed and the values for Area 124 were substituted for Area 125 (Section 3.3).

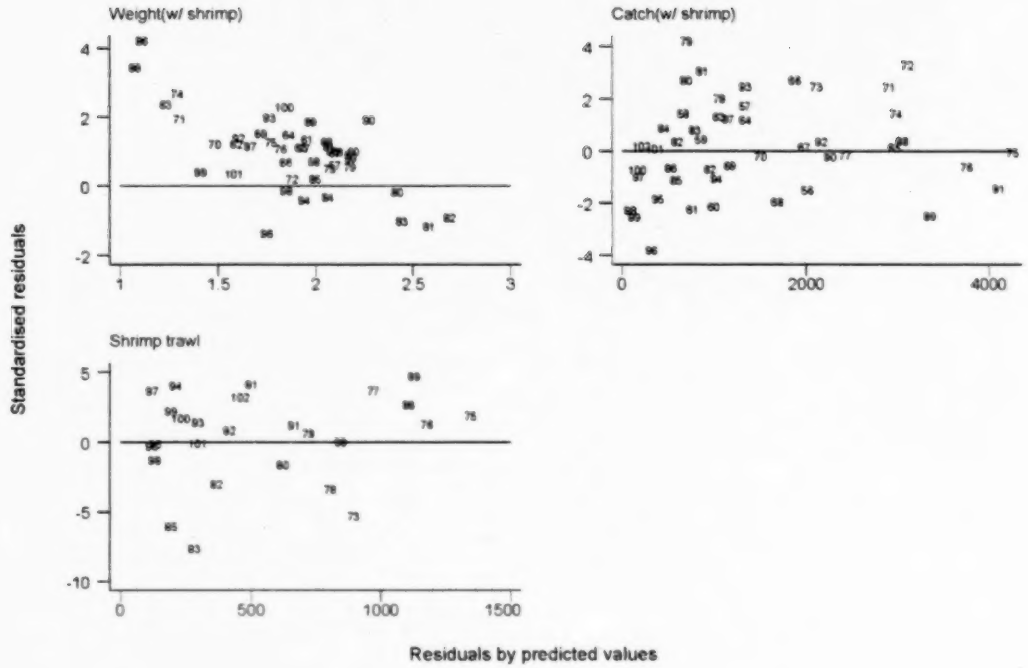

Figure 13. Residuals plotted against predicted values for the model run which included the shrimp trawl data (Table 8).

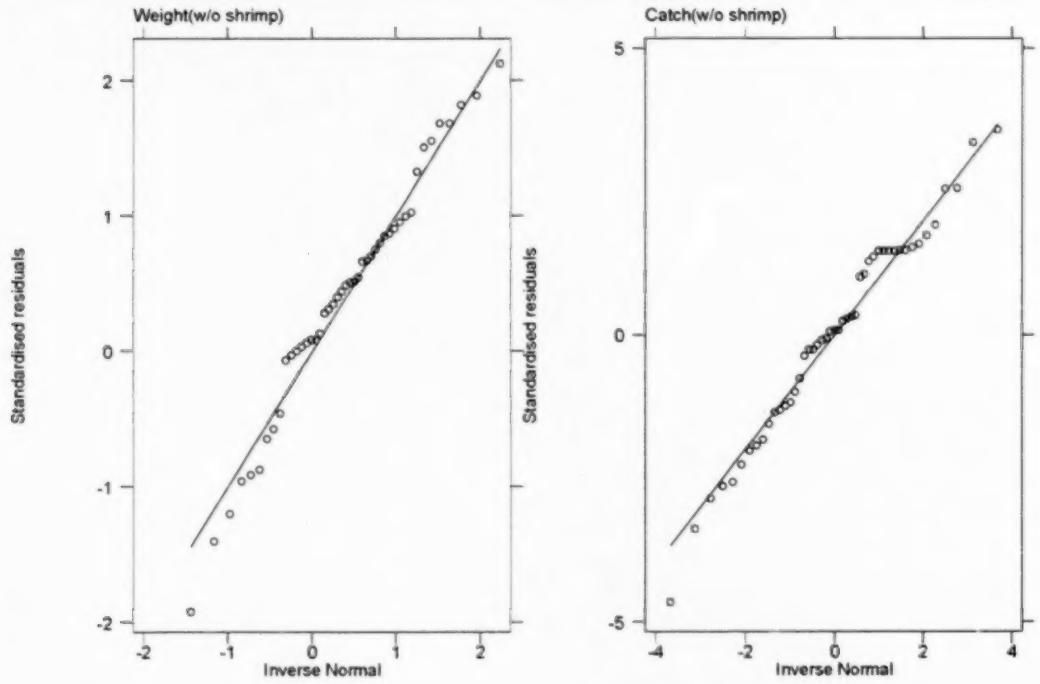

Figure 14. Q-Q plots for each dataset in the model run which did not include the shrimp trawl data (Table 8).

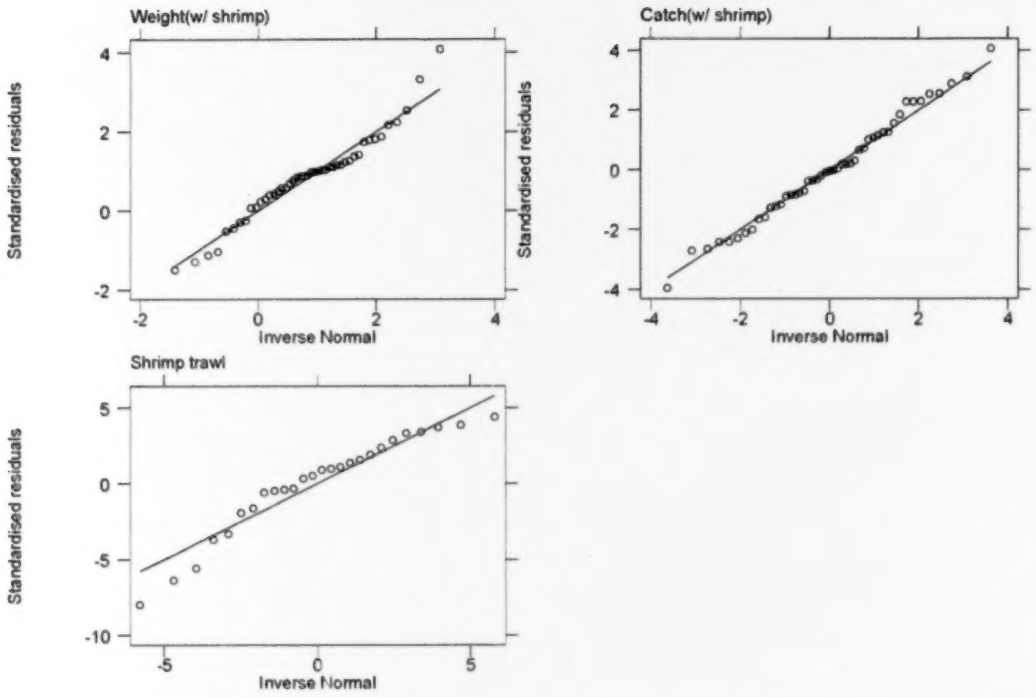

Figure 15. Q-Q plots for each dataset in the model run which included the shrimp trawl data (Table 8).

Model diagnostics are not very good, with the standard deviations of the standardised residuals well above 1.0 for both the catch data and the shrimp trawl indices (Table 8). The expected value for this statistic is about 1.0 if the fits to the model data conform to the assumption of normality and a value greater than 1.0 indicates that the relative weight for that data set is too high. Q-Q plots for both models indicate reasonable conformity to the normality assumptions for catch and mean weight with some large outliers at the tails of these distributions (Figure 14 and Figure 15). The adherence to the log-normal assumption for the shrimp trawl data does not seem to be as strong as it is for the catch or mean weight data (Figure 15).

Experimentation with reducing the weight on the catch data in either of the two models (to bring the standard deviation of the standardised catch residuals down to the preferred value of 1.0) led to large shortfalls in the total catch explained by the model and to much poorer fits to the catch. The shortfalls generally were generally greater than 20,000 t, which was not an acceptable representation of the catch history. Therefore the model fits presented in this paper have been made using the weighting that was selected by Sinclair et al. (2001) so that comparability between the two assessments can be maintained (Table 8). Future versions of this model could be conditioned on catch rather than on effort which avoids the problem of not fitting very well to the catch history and allowing for other data weighting options.

Model predictions of reference points of management interest were made over a range of catch levels by estimating the F required to take each catch from the beginning year biomass for 2003/04. The reference point predictions based on the model which did not include the shrimp trawl data

were more optimistic than those presented by Sinclair et al (2001), with the catch level which maintains the current stock size rising to 570 t compared to the 390 t previously estimated (Table 8) and the catch threshold to maintain the exploitation rate at F_{MSY} is estimated at 510 t compared to the 250 t previously estimated by Sinclair et al. (2001). The current biomass is estimated to be 39% of B_{MSY} and is not predicted to rise above B_{MSY} even if the catch were set to zero (Table 8), which are consistent with the reference point predictions made by Sinclair et al (2001). The more optimistic predictions using the updated model are explained by the inclusion of new data showing an increasing abundance.

The reference point predictions based on the model run which included the shrimp trawl data are more optimistic than those from the model run that did not use these data. This model estimates that the stock status is currently at B_{MSY} and is predicted to remain above that level for catch levels that are below 2,190 t (Table 8). The catch level which will causes the biomass to decrease between 2003/04 to 2004/05 is 690 t while a catch level of 1,290 t will drop the exploitation rate below F_{MSY}.

Note that the B_{MSY} reference point is estimated at a lower level and the F_{MSY} reference point is estimated at a higher level for this model run which included the shrimp trawl data compared to the model run which did not include shrimp trawl data. The differences in these derived parameters reflect the well-known trade-off that occurs in production models between the parameters which describe the stock size (scaling parameter) and the productivity (Hilborn & Walters 1992). These parameters are not well estimated in either model and consequently the reference point values are also not well estimated. Future assessments using this model should move away from the deterministic approach used here and adopt a probabilistic approach (for instance, a Bayesian model) which searches over the range of possible parameter values and provides managers with calculated estimates of the uncertainty associated with the management advice.

6.0 DISCUSSION

The model which includes the shrimp trawl data is in principle preferable to the model which does not. The former model makes use of all the available data and makes an explicit prediction of the beginning year biomass which is applicable to the current fishing year. This is because the shrimp survey is conducted in the spring and the resulting index provides an observation relevant to the beginning year biomass for the current fishing year. Figure 3 and Figure 6 demonstrate that this survey appears to correspond reasonably well to the CPUE index in the same year, which makes it a useful tool for making decisions on future levels of allowable catch. This model run indicates that the current stock status at the beginning of 2002/03 is approximately at B_{MSY}, but that catches in 2003/04 of 690 t would cause the stock to decline. Higher catch levels will bring the stock level below B_{MSY} (2,190 t) and below F_{MSY} (1,290 t).

The model diagnostics indicate that the residuals from the fits to the data are not completely normal, which means that some of the model assumptions are not being met. However, it was decided that making adjustments to this model in this year would be superseded by a major reappraisal of the model which could occur in the coming year. Also, it is likely that minor adjustments would not improve the overall performance. It is suggested that the current model could be improved by:

- converting to a probabilistic approach which will allow the estimation of the uncertainty associated with the predictions of stock status at different catch levels (as discussed in Section 5.0).
- conditioning the model on catch rather than on effort.
- incorporating the estimation of the growth rate parameters into the model likelihood. This will require obtaining the original age-length data that were used to estimate the growth parameters presently used in the model.
- finding data weighting options which address the apparent imbalance between the datasets that are indicated in the model diagnostics (Table 8).

It is proposed to continue to use a delay-difference approach as this model structure suits a situation where data are limited and there are insufficient data to justify an age-structured approach. However, other model structures should also be investigated to determine if they provide more robust estimation properties.

7.0 RECOMMENDATIONS

- Adopt yield estimates based on the model results which incorporate all three sets of available data (mean weight, shrimp trawl indices and catches). The predictions are summarised in Table 9.
- Investigate revisions to the delay difference model as recommended in Section 6.0.

Table 9. Schedule of projected catches (in tonnes) for 2003/04 with model estimated indicators based the model run which included the shrimp trawl survey data. The reference point indicators provided are: the instantaneous fishing mortality ($F_{2003/04}$) associated with each projected catch, the estimated biomass at the beginning of the next fishing year ($B_{2004/05}$), the percent change in biomass from 2003/04 to 2004/05, the percent ratio of $B_{2004/05}$ with the estimated B_{MSY}, and the percent ratio of $F_{2003/04}$ with the estimated F_{MSY}.

$Catch_{2003/04}$ (t)	$F_{2003/04}$	$B_{2004/05}$	$\Delta\% = \frac{B_{2004/05}}{B_{2003/04}} - 1$	$\frac{B_{2004/05}}{B_{MSY}}\%$	$\frac{F_{2003/04}}{F_{MSY}}\%$
0	0.00	9,240	9.8%	137%	0%
60	0.01	9,171	9.0%	136%	4%
120	0.02	9,101	8.2%	135%	8%
180	0.03	9,031	7.3%	134%	13%
240	0.04	8,962	6.5%	133%	17%
300	0.05	8,892	5.7%	132%	21%
360	0.06	8,823	4.9%	131%	26%
420	0.07	8,753	4.0%	130%	30%
480	0.08	8,684	3.2%	129%	34%
540	0.09	8,615	2.4%	128%	39%
600	0.10	8,546	1.6%	127%	43%
660	0.11	8,476	0.7%	126%	48%
720	0.12	8,408	-0.1%	125%	53%
780	0.13	8,339	-0.9%	124%	57%
840	0.14	8,270	-1.7%	123%	62%
900	0.15	8,201	-2.5%	122%	67%
960	0.16	8,133	-3.3%	121%	71%
1,020	0.17	8,064	-4.2%	120%	76%

$Catch_{2003/04}$ (t)	$F_{2003/04}$	$B_{2004/05}$	$\Delta\% = \frac{B_{2004/05}}{B_{2003/04}} - 1$	$\frac{B_{2004/05}}{B_{MSY}}\%$	$\frac{F_{2003/04}}{F_{MSY}}\%$
1,080	0.18	7,995	-5.0%	119%	81%
1,140	0.19	7,927	-5.8%	118%	86%
1,200	0.21	7,858	-6.6%	117%	91%
1,260	0.22	7,790	-7.4%	116%	96%
1,320	0.23	7,721	-8.2%	115%	101%
1,380	0.24	7,653	-9.0%	114%	106%
1,440	0.25	7,585	-9.8%	113%	111%
1,500	0.26	7,518	-10.7%	112%	117%
1,560	0.28	7,450	-11.5%	111%	122%
1,620	0.29	7,382	-12.3%	110%	127%
1,680	0.30	7,314	-13.1%	109%	133%
1,740	0.31	7,246	-13.9%	108%	138%
1,800	0.32	7,179	-14.7%	107%	144%
1,860	0.34	7,111	-15.5%	106%	149%
1,920	0.35	7,044	-16.3%	105%	155%
1,980	0.36	6,976	-17.1%	104%	161%
2,040	0.38	6,909	-17.9%	103%	167%
2,100	0.39	6,842	-18.7%	102%	172%
2,160	0.40	6,775	-19.5%	101%	178%
2,220	0.42	6,708	-20.3%	100%	184%
2,280	0.43	6,642	-21.1%	99%	190%
2,340	0.44	6,575	-21.8%	98%	197%

8.0 REFERENCES

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9.0 APPENDIX 1. DELAY DIFFERENCE MODEL

A delay-difference stock production model (Hilborn and Walters 1992) was used to estimate stock parameters and reference points relevant to management. The model uses two age groups, recruits and spawners. A stochastic Ricker stock-recruitment function was used to link the two groups. Recruitment to the spawning population and the fishery was assumed to be knife edged at age 2. Growth was assumed to follow a constant von-Bertalanffy function and the length-weight relationship was assumed to be constant. Input parameters for growth were obtained from Westrheim (1996) and were assumed to be known. The model is conditioned on fishing effort, estimated as the ratio of catch divided by catch per unit effort. The objective function includes terms for minimising the differences between the predicted and the observed catch, the predicted and the observed mean weight of the population, the predicted and observed biomass indices from the shrimp trawl survey, and minimising the recruitment deviations relative to the mean recruitment. The model used in this assessment differs from the model described by Sinclair et al. (2001) by the addition of the shrimp trawl survey indices into the model fitting procedure.

The following tables describe the model parameters, data, dynamics and likelihoods.

Estimated Parameters

B_0	unfished population biomass
γ	ratio B_1 / B_0, population size in year 1 relative to unfished population size
δ	steepness of stock-recruitment curve, multiplier between slope at unfished equilibrium and at the origin of the stock recruitment curve
q_c	fishery catchability
q_s	shrimp trawl survey catchability
M	natural mortality rate
ϕ_t	recruitment anomalies in year t (there are 47 of these parameters)

Fixed parameters (growth parameters from Westrheim 1996)

Parameter	Value	Description
L_∞	89.48	Maximum length in von-Bertalanffy growth equation
k	0.307	growth rate parameter in von-Bertalanffy growth equation
t_0	0.116	time at L_0 in von-Bertalanffy growth equation
a	7.38E-06	slope of length – weight relationship (kg)
b	3.0963	Exponent of length – weight relationship
r	2	age of knife edge recruitment to fishery and spawning population
ρ	0.836	slope of the Ford-Walford plot, age 2-20
α	1.41	Intercept of Ford-Walford plot, age 2-20

Annual Input Data

E_t	fishing effort in year t
C_t	weight of catch in year t
w_t	mean weight of individuals in the population in year t
S_t	shrimp trawl survey index in year t

Derived parameters:

$w_r = a(L_\infty(1-e^{-k(r-t_0)}))^b$	weight at the age of recruitment
$S = e^{-M}$	natural survival rate
$\overline{w} = \frac{(S\alpha + w_r(1-S))}{1-\rho S}$	average body weight in the unfished population
$N_0 = \frac{B_0}{\overline{w}}$	unfished equilibrium population numbers
$R_0 = N_0(1-S)$	unfished equilibrium recruitment
$s_0 = \frac{\delta R_0}{B_0}$	maximum recruitment survival, slope at the origin of stock recruitment curve
$\beta = \frac{-\ln(1/\delta)}{B_0}$	recruitment capacity

Model Equations

$F_t = q_c E_t$	instantaneous fishing mortality in year t
$N_t = N_{t-1}e^{(-M-F)} + R_{t-r}$	population numbers in year t
$B_t = (\alpha N_{t-1} + \rho B_{t-1})e^{(-M-F)} + w_r R_{t-2}$	population biomass in year t
$\hat{w}_t = \frac{B_t}{N_t}$	predicted mean weight of individuals in the population in year t
$R_t = s_0 B_t e^{(-\beta B_t)} e^{(\phi_t)}$	recruitment in year t
$\hat{C}_t = \frac{B_t(1-e^{(-M-F_t)})F_t}{M+F_t}$	predicted catch in year t
$\hat{S}_t = q_s B_t$	predicted shrimp biomass index in year t
$C_t = \frac{B_t(1-e^{(-M-F_t)})F_t}{M+F_t}$	solve F_t for in years 2002/03 [where applicable] and 2003/04 where catch is assumed to be known
$U_t = C_t / B_t$	Exploitation rate in year t

Objective Function:

The following function was minimised for the model run where only the catch and weight data were included in the model:

$$n\ln\sigma_\phi + \frac{1}{2\sigma_\phi^2}\sum(\phi^2) + n\ln\sigma_c + \frac{1}{2\sigma_c^2}\sum(\ln C_t - \ln\hat{C}_t)^2 + n\ln\sigma_w + \frac{1}{2\sigma_w^2}\sum(\ln w_t - \ln\hat{w}_t)^2$$

The following terms were added to the above objective function when the shrimp trawl data were added to the model:

$$n\ln\sigma_s + \frac{1}{2\sigma_s^2}\sum(\ln S_t - \ln\hat{S}_t)^2$$

The residual standard deviations for weighting the components of the objective function were arbitrarily set to $\sigma_\phi = 0.4$, $\sigma_w = 0.2$, $\sigma_c = 0.2$ and $\sigma_s = 0.2$ for the recruitment anomalies, mean weights, catch and shrimp biomass indices respectively. It was reasoned that the recruitment process error should have the highest variability of the three. The variation in mean weight at age may reflect, to a large extent, observations error while the variation around predicted catch would reflect mainly process error in catchability.

Equilibrium Predictions

$S_e = e^{-M-F}$	survival rate with fishing at equilibrium
$w_e = \frac{S_e\alpha + w_r(1-S_e)}{1-\rho S_e}$	average weight at equilibrium
$B_e = -\ln(\frac{(w_e - S_e\alpha - S_e\rho w_e)}{w_r s_0 w_e})/\beta$	population biomass at equilibrium
$N_e = \frac{B_e}{w_e}$	population numbers at equilibrium
$Y_e = \frac{B_e(1-e^{(-M-F)})F}{M+F}$	yield at equilibrium

10.0 APPENDIX 2. DETAILED MODEL OUTPUT

Appendix Table 1. Model output, predicted values, recruitment deviations (ϕ_t), exploitation rate (U_t), and standardised residuals for delay-difference model fitted to the catch data, the weight data and the shrimp trawl index. Model input observations can be found in Table 1 and Table 5.

	Model output			Model predicted values					Standardised residuals		
Fishing year	Biomass (t)	Numbers	Recruits	Weight	Catch	Shrimp survey	ϕ_t	U_t	Weight	Catch	Shrimp survey
1956	12,720	5,856	2,337	2.172	2,005	836	-0.182	20.5%	0.763	-1.669	–
1957	10,350	4,946	1,575	2.093	1,324	680	-0.516	16.7%	0.473	1.550	–
1958	9,231	4,647	1,470	1.987	650	607	-0.539	9.2%	0.578	1.258	–
1959	8,564	3,939	1,806	2.174	849	563	-0.299	13.0%	0.679	0.301	–
1960	7,419	3,392	3,067	2.187	982	487	0.304	17.3%	0.864	-2.301	–
1961	6,589	3,379	8,231	1.950	752	433	1.359	14.9%	1.223	-2.425	–
1962	7,438	4,678	2,944	1.590	944	489	0.262	16.6%	1.097	-0.866	–
1963	12,804	10,419	3,873	1.229	1,039	841	0.321	10.6%	2.231	1.145	–
1964	15,159	8,163	3,838	1.857	1,326	996	0.288	11.5%	1.365	1.005	–
1965	15,208	7,924	2,224	1.919	2,953	999	-0.258	25.2%	0.991	-0.052	–
1966	13,188	7,159	2,170	1.842	1,864	867	-0.264	18.4%	0.559	2.540	–
1967	11,497	5,497	3,116	2.091	1,967	755	0.131	22.3%	0.832	-0.026	–
1968	9,362	4,565	4,929	2.051	1,676	615	0.665	23.3%	1.148	-2.127	–
1969	8,712	5,079	9,487	1.715	1,159	572	1.352	17.4%	1.401	-0.731	–
1970	10,770	7,282	3,317	1.479	1,490	708	0.215	18.0%	1.092	-0.373	–
1971	16,704	12,832	2,782	1.302	2,897	1,098	-0.037	22.6%	1.811	2.264	–
1972	16,661	8,886	11,733	1.875	3,103	1,095	1.403	24.2%	0.067	3.104	–
1973	13,543	6,557	5,031	2.065	2,103	890	0.572	20.2%	0.383	2.275	-5.597
1974	18,905	14,665	5,120	1.289	2,972	1,242	0.584	20.5%	2.534	1.243	–
1975	20,426	11,567	3,607	1.766	4,261	1,342	0.250	27.1%	1.144	-0.221	1.553
1976	17,887	9,849	2,431	1.816	3,755	1,175	-0.168	27.2%	0.959	-0.782	0.978
1977	14,749	7,624	2,148	1.935	2,417	969	-0.290	21.3%	0.973	-0.327	3.383
1978	12,189	5,792	1,324	2.104	1,045	801	-0.740	11.2%	0.861	1.836	-3.693
1979	10,914	5,031	963	2.169	686	717	-1.026	8.2%	0.421	4.056	0.314
1980	9,437	3,912	669	2.413	682	620	-1.336	9.5%	-0.305	2.523	-1.939
1981	7,600	2,948	759	2.578	857	499	-1.106	14.7%	-1.295	2.879	3.834
1982	5,577	2,078	853	2.684	590	366	-0.803	13.8%	-1.040	0.174	-3.324
1983	4,295	1,762	730	2.437	779	282	-0.776	23.6%	-1.141	0.645	-7.996
1984	3,308	1,608	4,302	2.057	442	217	1.198	17.4%	-0.451	0.701	–
1985	2,934	1,475	1,955	1.990	571	193	0.507	25.3%	0.075	-1.294	-6.390
1986	5,457	4,919	13,718	1.109	520	359	1.989	12.5%	4.083	-0.831	–
1987	7,260	4,369	2,005	1.662	1,135	477	-0.109	20.4%	1.025	1.063	–
1988	16,809	15,667	1,990	1.073	3,042	1,104	-0.371	23.5%	3.310	0.194	2.364
1989	17,153	8,720	2,464	1.967	3,349	1,127	-0.157	25.4%	1.730	-2.666	4.390
1990	12,791	5,638	2,619	2.269	2,255	840	-0.070	22.9%	1.782	-0.399	-0.322
1991	10,093	4,899	1,322	2.060	4,106	663	-0.682	51.8%	1.027	-1.607	0.890
1992	6,316	3,943	765	1.602	2,155	415	-0.992	43.7%	1.259	0.178	0.511
1993	4,513	2,566	420	1.759	1,325	297	-1.365	37.8%	1.857	2.293	1.101
1994	3,209	1,659	635	1.934	1,009	211	-0.691	40.4%	-0.530	-1.223	3.679
1995	2,024	974	662	2.079	377	133	-0.261	24.2%	0.882	-2.007	-0.479
1996	1,827	1,048	518	1.743	311	120	-0.415	22.2%	-1.506	-3.975	-0.621
1997	1,859	1,119	1,508	1.661	170	122	0.638	12.0%	–	-1.175	3.310
1998	1,974	1,070	814	1.845	82	130	-0.032	5.5%	-0.263	-2.431	-1.621
1999	2,922	2,075	1,840	1.408	127	192	0.449	5.7%	0.283	-2.719	1.874
2000	3,512	1,911	3,700	1.838	154	231	1.000	5.8%	2.158	-0.904	1.343
2001	4,497	2,849	1,640	1.578	346	295	0.000	10.1%	0.222	-0.098	-0.394
2002	6,981	5,136	2,187	1.359	199	459	0.000	3.8%	–	0.013	2.851